Secondhand tobacco smoke tracers measured in smoking and nonsmoking areas within a café in Buenos Aires, Argentina.

Hugo Destaillats [1,*], Ernesto Sebrié [2], Toshifumi Hotchi [1],
Stanton A. Glantz [2] and Lara A. Gundel. [1]

[1] *Indoor Environment Department, Lawrence Berkeley National Laboratory, Berkeley, California, USA*
[2] *Center for Tobacco Control Research and Education, University of California, San Francisco, USA.*

Abstract

A new law mandating separation of smoking and non-smoking areas in bars and restaurants was approved by the legislature of the city of Buenos Aires in 2005 and will take effect on October 2006. Such separations have not proven effective at controlling secondhand smoke (SHS) in other countries, but the question remains as to whether differences in building practices, climate and smoking patterns might lead to a different result in Argentina. In this study, we developed a novel sampling and analytical approach for the quantitative assessment of nonsmokers' exposure to SHS that relies on sequentially measuring concentrations of gas-phase tracers in smoking and non-smoking areas. We collected air samples in a typical Buenos Aires café using a portable handheld pump and Tenax-TA sorbent tubes. Tobacco amines and other nitrogenated organic tracers present in the samples were analyzed by thermal desorption-gas chromatography with nitrogen and phosphorus detection (TD/GC/NPD). Concentrations of ten SHS tracers in non-smoking areas were not significantly different from those measured in smoking areas. For nicotine, gas phase concentrations were between 2.8 and 5.3 $\mu g\ m^{-3}$, and the nonsmoking/smoking (NS/S) concentration ratios ranged between 0.68 and 1.29. For most other tracers, NS/S concentration ratios were in the range 0.7 – 1.2. The methodology proposed in this study provides good quantitative evaluation of the efficacy of partial smoking restrictions, and allows for its deployment in larger field studies. Our results indicate that, in the studied café, exposure to toxic SHS constituents in the non-smoking area was not mitigated by its separation from the smoking area.

[*] corresponding author E-mail: HDestaillats@lbl.gov

Introduction

The World Health Organization's Framework Convention on Tobacco Control (WHO/FCTC) recommends, among other measures, the creation of 100% smokefree enclosed environments to reduce the morbidity and mortality related to tobacco use and exposure (World Health Organization, 2003). Argentina signed the FCTC but is not among the 124 countries that have ratified it (as of April 2006). Smokefree workplaces not only protect nonsmokers from the toxins in secondhand smoke, but also provide an environment that facilitates smokers' decisions to reduce consumption or stop smoking; smokefree workplaces are associated with a 29% reduction in cigarette consumption (Fichtenberg and Glantz, 2002). The tobacco industry responded by organizing the hospitality (Ritch and Begay, 2001; Dearlove et al., 2002) and gaming (Mandel and Glantz, 2004) industries to oppose these policies. In a complementary effort, the tobacco industry has promoted nonsmoking and smoking areas and ventilation systems as an alternative to 100% smokefree environments (Drope et al., 2004) through the industry's "accommodation" and "courtesy of choice" programs (Dearlove et al., 2002).

Despite numerous attempts by health advocates in the last decades, the tobacco industry successfully prevented meaningful tobacco control legislation in Argentina (Sebrié et al., 2005).Consistent with the industry's "courtesy of choice" program, the city of Buenos Aires passed a local law in 1994 to delimit smoking and nonsmoking areas in restaurants, bars and cafés. In places with floor areas between 40 and 100 square meters, 20% of the area was assigned for nonsmokers. For those larger than 100 square meters, the nonsmoking area reached 35% (Ordinance 47.670, 1994). More than ten years later (September 2005), the city Legislature approved a law to end smoking in schools, health care facilities and government buildings, but stopped short of mandating 100% smokefree environments in bars and restaurants. The new measure establishes smoking (30%) and nonsmoking areas (70%) in bars, restaurants and cafés larger than 100 square meters. Also consistent with the tobacco industry's ventilation strategy, the measure requires the operation of independent ventilation systems that guarantee "the purification of air, the elimination of smokes," [and] "minimize its impact over the employees and avoid the

transport of particles towards areas where smoking is banned" (Ley 1799, 2005). These partial smoking restrictions will take effect starting in October 2006.

The new Buenos Aires law has spurred public debate and reflects a trend towards increased societal awareness about the harmful effects of secondhand smoke. In a population with high smoking prevalence of ~40% (Shafey et al., 2003) and where tobacco is still deeply entrenched in the popular culture, partial restrictions such as the separation of smoking and nonsmoking areas have been welcomed by the press and many policymakers as a step in the right direction. However, the ineffectiveness of such partial restrictions to prevent nonsmokers' exposures to tobacco smoke has been documented in various studies:

a) reported workers' exposures (measured as levels of salivary cotinine, a stable metabolite of nicotine) in bars and restaurants that permit customers to smoke only in restricted areas were substantially higher than in smokefree restaurants and bars (Bates et al., 2002);
b) the use of mechanical ventilation (extractor fans, heating, ventilation and air conditioning systems) in a restaurant with smoking and non-smoking areas within a single room did not have a significant effect on SHS marker concentrations measured in both areas (Carrington et al., 2003; Gee et al., 2005).
c) reports showing transport of SHS constituents through airplane cabin led the US Congress to end smoking in commercial US flights (Henningfield and Rose, 2001).
d) the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 62 concludes that it is not possible to have acceptable indoor air quality when smoking is present, regardless of the type of ventilation system that is present (Glantz and Schick, 2004).

In this paper, we report air concentrations of nicotine and other gas-phase SHS tracers measured in smoking and non-smoking areas of a café in Buenos Aires. A recent survey of seven Latin-American cities (Buenos Aires, Montevideo, Rio de Janeiro, Santiago, San José, Asunción and Lima) showed that airborne nicotine (the most

commonly measured SHS tracer) was higher in bars and restaurants than in other public places studied, which also included airports, hospitals, schools and city government buildings (Navas-Acien et al., 2003). The same conclusion was reached by a similar study performed in seven European cities (Nebot et al., 2005). Hence, bars, cafés, pubs and restaurants are an important SHS exposure setting for the general population. Hospitality workers can be seriously affected by exposure to SHS in the workplace.

The goal of this study is to develop and test a sampling and analytical technique for the determination of airborne SHS tracer concentrations with high spatial and time resolution. The sequential (near-simultaneous) measurement of indoor air markers in smoking and non-smoking areas in short periods of 60-90 minutes is a simple and accurate method to quantitatively assess the effectiveness of a partial restrictions regime at controlling SHS and protecting nonsmokers.

Experimental methods

Air samples were collected during evening hours inside a café located in the traditional Palermo district of the city of Buenos Aires. The setting was considered typical of mid- and large-sized Argentinean cafés (*confiterías*), serving coffee, tea, alcoholic and non-alcoholic beverages and daytime snacks. This sampling location was selected after screening numerous large cafés and bars to find the following conditions: a floor area of more than 100 m^2 and a well-defined smoking area with the largest possible number of tables. In the café selected for this study, a total of 48 tables occupied a single floor of 18 m by 12 m, with a roof height of 6 m. Sixteen of those tables were designated for non-smokers, as indicated in the scheme presented in Figure 1. A visible sign identified each of those tables as being within the non-smoking area, but no physical partition existed between smoking and non-smoking areas. The alphanumeric labels assigned to individual tables in Figure 1 serve to identify sampling locations and to evaluate approximate distance to smoking patrons in each sample. Full occupancy was about 200 customers, but during sampling periods only 20-60% of the tables were occupied, predominantly in the smoking area. Patrons sitting in the non-smoking area were in strict compliance with

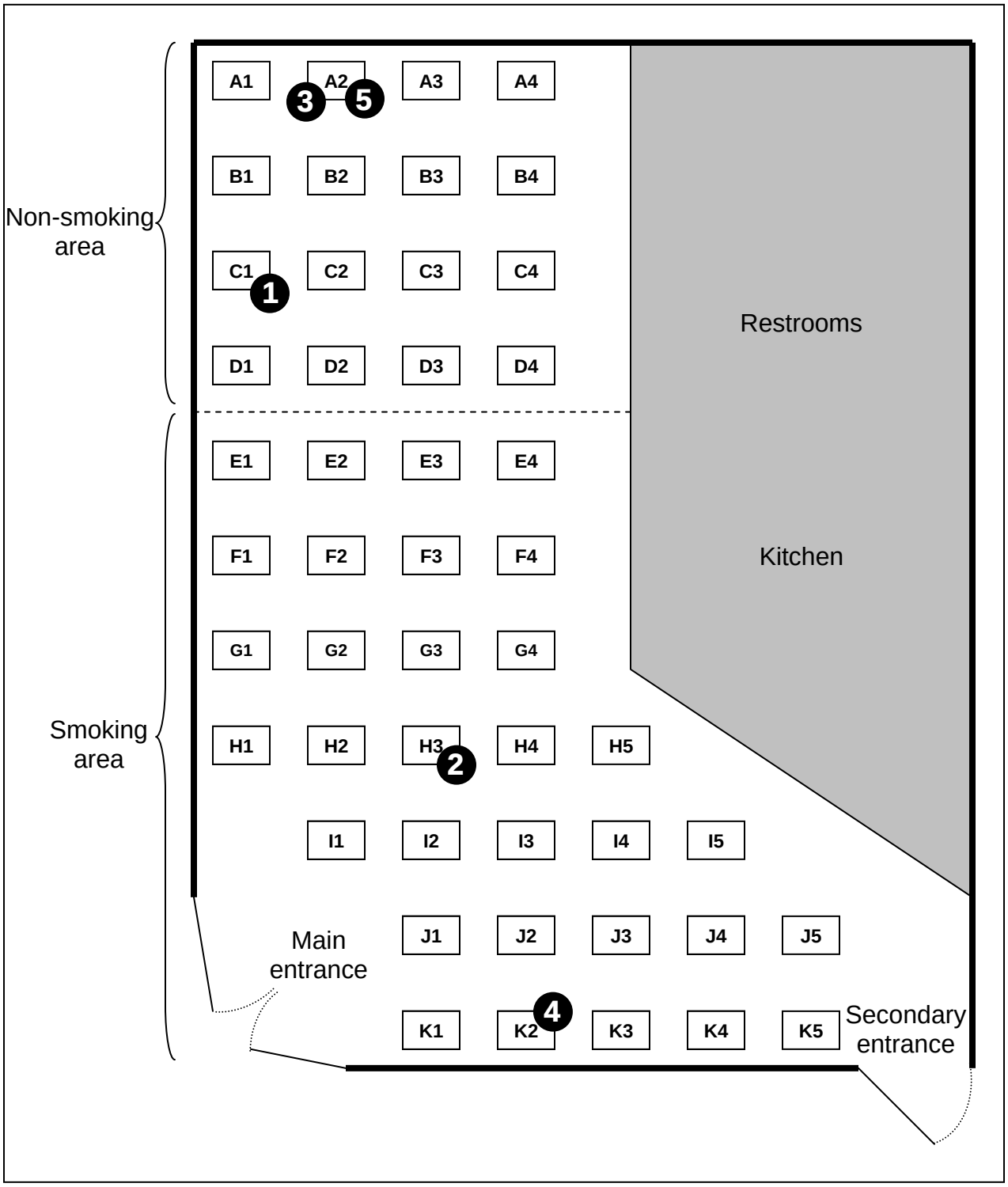

Figure 1: *Scheme of the sampling site, indicating smoking and non-smoking areas, and tables where sampling was carried out (black circles numbered 1-5).*

the smoking restriction. The establishment was provided with mechanical ventilation and central air conditioning. Windows were closed due to high outside temperatures (near 30 ^{o}C), and the air conditioning system was in operation continuously during sampling.

Air sample collection was carried out using Tenax-TA ® sorbent tubes (Supelco, Model 25055) connected to a portable battery-operated pump (SKC Inc, Fullerton CA, Model AirChek 2000). The apparatus was inconspicuous due to its small size and low noise level. It was placed inside a handbag, with the sorbent tubes sticking out in a way that allowed for sampling in the vicinity of the breathing zone of a sitting customer. The pump was operated at a constant flow rate, and the flow was split into two parallel channels, labeled A and B. One sorbent tube was connected to each channel, allowing for the collection of duplicate samples. In each of those channels, a constant pressure controller (CPC, SKC Inc. Model 224-26) was used to maintain a constant pressure difference between the pump and the sorbent tube. The flows were calibrated individually for each tube operating under these conditions, being in the range of 195 - 245 cm^3 min^{-1}. Experimental uncertainties in the measurement of individual flows were < 2 % relative standard deviation (%RSD).

Samples of 64-84 min duration were collected at tables in the smoking and non-smoking areas. During each of those sampling periods, the number and location of cigarettes smoked were recorded. In order to better describe the smoking pattern observed during each sample, we divide the total number of cigarettes smoked in four different groups: less than 2 m (corresponding to the first circle of tables in the immediate vicinity of the sampling point), between 2 and 5 m (second circle of tables), 5-10 m (third and fourth circles) and more than 10 m. Specific details of each sample, including duration, location and number of cigarettes smoked during sampling at various distances from the sampling location, are given in Table 1.

Sorbent tubes were pre-conditioned before sampling by heating to 250 ^{o}C under a stream of He for 1 hour. After sampling, tubes were kept in a freezer for one week before analysis. Sample analysis was carried out by gas chromatography with a thermal

desorption inlet and a nitrogen and phosphorus detector (TD/GC/NPD). We used a Hewlett Packard HP 5890 GC equipped with a Perkin-Elmer ATD 400 automatic multitube thermal desorber. Nicotine and other SHS tracers were quantified using multipoint calibrations referenced to an internal standard (quinoline). Analyte identification and quantification was carried out with authentic standards for nicotine (Sigma >99%), myosmine (Sigma), pyrrole (Aldrich, >98%), 3- and 4-picoline (Aldrich, 99%), pyridine (Aldrich, 99%), 3-hydroxypyridine (Sigma-Aldrich, 98%), cotinine (Sigma, 98%), N-methylformamide (Aldrich, 99%), N,N-dimethylformamide (Aldrich, 99%) and nicotinaldehyde (3-pyridincarboxaldehyde, Aldrich 98%). For the quantification of 3-ethenylpyridine (3-EP), its isomer 4-ethenylpyridine (Aldrich, 95%) was used as a surrogate.

Table 1: *Experimental conditions: sampling time, duration, location and proximity to smokers.*

Sample	**Time (duration)**	**Sampling location (section)**	**Number of cigarettes smoked at a distance of**			
			< 2 m	**2-5 m**	**5-10 m**	**> 10 m**
Day 1 (December 29th 2005)						
1	16:09 – 17:24 (75 min)	C1 (non-smoking)	0	2	4	1
2	17:37 – 18:50 (73 min)	H3 (smoking)	6	13	16	0
3	18:55 – 19:59 (64 min)	A2 (non-smoking)	0	0	6	1
Day 2 (January 2nd 2006)						
4	17:00 – 18:14 (74 min)	K2 (smoking)	2	3	7	2
5	18:16 – 19:38 (84 min)	A2 (non-smoking)	0	0	11	2

Results and Discussion

The concentration of ten gas phase SHS tracers determined in each of the five samples is presented in Table 2. Reported analyte concentrations are the average of two determinations from co-located duplicate samples. The experimental error was calculated as one standard deviation from the mean, when the analyte concentration was higher than 1 μg m^{-3}, and as two standard deviations for samples with lower concentrations (< 1 μg m^{-3}), in order to consider a larger experimental uncertainty for analytes with lower concentration. Among the studied SHS components, nicotine is the most commonly used tracer. Nicotine, as well as other SHS gas-phase components, such as pyridine, pyrrole, myosmine and 3-ethenylpyridine, have been previously reported in tobacco smoke characterization studies (Jenkins et al., 2000; Singer et al., 2002; Singer et al., 2003). Other analytes reported in Table 2 (N-methylformamide, cotinine, nicotinaldehyde) have been recently identified as stable products of nicotine oxidation in the indoor environment (Destaillats et al., 2006).

Gas-phase nicotine concentrations were between 2.8 and 5.3 μg m^{-3}; these values are higher than levels considered acceptable in terms of health risk according to lung cancer and heart disease models (Repace and Lowrey, 1993; Repace et al., 1998).The nicotine levels in our study compare very well with reported measurements of gas-phase nicotine carried out in bars, restaurants and other hospitality facilities using passive sampling consisting on a filter badge coated with sodium bisulfate (Hammond and Leaderer, 1987). In those passive collection studies, determinations of nicotine concentration typically represent averages of between 1 and 2 weeks, which include non-operation periods. Navas-Acien et al (2003) measured a median nicotine concentration by passive sampling in a total of 44 bars in seven Latin-American cities of 3.65 μg m^{-3}, with an interquartile range of 1.55-5.12 μg m^{-3}. For restaurants (97 cases), the same study found a median of 1.24 μg m^{-3} nicotine with an interquartile range of 0.41-2.48 μg m^{-3}. Considerably higher levels of nicotine were measured in a study of seven European cities by the same passive sampling method (Nebot et al., 2005). Median values in European discos or bars (35 cases) were mostly between 19 and 122 μg m^{-3}. (SHS levels were

Table 2: *Determination of SHS tracer concentrations, in $\mu g\ m^{-3}$ ± S.D,. in non-smoking (NS) and the smoking (S) areas. Values in parenthesis are relative standard deviations (% RSD).*

SHS tracer	Vap press (mmHg)[a]	Day 1			Day 2	
		Sample 1 (NS)	Sample 2 (S)	Sample 3 (NS)	Sample 4 (S)	Sample 5 (NS)
N,N-dimethyl formamide	3.87	0.49 ± 0.16 (32 %)	0.59 ± 0.34 (60 %)	0.65 ± 0.06 (11 %)	0.77 ± 0.15 (20 %)	0.60 ± 0.26 (42 %)
N-methylformamide	0.253	0.53 ± 0.08 (14 %)	0.69 ± 0.04 (5 %)	0.61 ± 0.18 (30 %)	0.53 ± 0.01 (2 %)	0.54 ± 0.14 (26 %)
pyridine	20.8	2.74 ± 0.14 (5 %)	3.57 ± 0.24 (7 %)	4.0 ± 0.7 (18 %)	3.13 ± 0.05 (2 %)	2.76 ± 0.05 (2 %)
pyrrole	8.36	1.24 ± 0.07 (6 %)	1.59 ± 0.07 (4 %)	1.88 ± 0.04 (2 %)	1.47 ± 0.05 (3 %)	1.45 ± 0.15 (11 %)
3- + 4-picoline[b]	6.05 / 5.77	1.06 ± 0.04 (4 %)	1.24 ± 0.10 (8 %)	1.35 ± 0.03 (2 %)	1.09 ± 0.00 (0 %)	1.06 ± 0.11 (11 %)
3-ethenylpyridine[c]	1.70	1.68 ± 0.06 (4 %)	2.1 ± 0.17 (9 %)	2.26 ± 0.04 (2 %)	1.62 ± 0.07 (4 %)	1.66 ± 0.18 (11 %)
nicotinaldehyde	0.568	0.48 ± 0.06 (14 %)	0.49± 0.10 (20 %)	0.45± 0.20 (42 %)	0.36± 0.08 (22 %)	0.31 ± 0.10 (30 %)
myosmine	n.a.	1.07 ± 0.04 (4 %)	1.05 ± 0.14 (14 %)	1.07 ± 0.10 (10 %)	0.92 ± 0.46 (50 %)	0.72 ± 0.52 (74 %)
3-hydroxypyridine	0.552	0.32 ± 0.01 (2 %)	0.36 ± 0.02 (2 %)	0.32 ± 0.08 (26 %)	0.28 ± 0.12 (44 %)	0.23 ± 0.12 (74 %)
nicotine	0.038	2.80 ± 0.02 (1 %)	4.1 ± 0.2 (5 %)	5.3 ± 0.5 (9 %)	4.2 ± 0.7 (17 %)	4.1 ± 0.9 (22 %)
cotinine	8.6×10^{-5}	0.11 ± 0.02 (14 %)	0.11 ± 0.02 (14 %)	0.11 ± 0.4 (30 %)	0.10 ± 0.04 (38 %)	0.07 ± 0.04 (102 %)

a: Source: (Howard and Meylan, 1997)
b: 3-picoline and 4-picoline coeluted, we report the added concentration.
c: we used 4-ethenylpyridine as quantification surrogate.

presumably higher in discos, which makes it difficult to compare directly with other studies involving bars exclusively.) For European restaurants, median concentrations were between 0.01 and 18 μg m^{-3} (100 cases). In both multi-city studies, concentrations measured in non-smoking areas were often similar to concentrations in areas where smoking was allowed within the same facility. In the Latin-American study, some nonsmoking areas showed even higher concentrations than adjacent smoking areas, but a quantitative comparison between different sections of the same facilities was not performed. Very high mean nicotine levels were also measured in a recent US study carried out in establishments identified as the "5 B's": bars (31.1 μg m^{-3}), bowling alleys (10.5 μg m^{-3}), billiard halls (13.0 μg m^{-3}), betting establishments (9.8 μg m^{-3}) and bingo parlors (76 μg m^{-3}) (Siegel and Skeer, 2003).

Our measurements, as well as these reported literature values, indicate that bars and restaurants are a critical setting for SHS exposure. Hospitality workers are a population particularly exposed to the impairing effects of secondhand smoke. Repace and coworkers (Repace and Lowrey, 1993; Repace et al., 1998) estimated workplace exposure to SHS using airborne nicotine concentrations, and concluded that a working lifetime of 45 years in an indoor environment with 2.0 μg m^{-3} nicotine presented a lung cancer risk of 3:10,000. Such nicotine levels are very close or lower than average reported values. Area samples such as those collected in our study, as well as most SHS tracer measurements reported in the literature, were found to exhibit a very good correlation with personal exposure measured from air near the breathing zone of bartenders and wait staff (Maskarinec et al., 2000).

In order to compare quasi-simultaneous exposures in non-smoking (NS) vs. smoking (S) areas, we calculated the (NS/S) concentration ratio of individual tracers. We used for this evaluation the five tracers with highest concentrations, which allowed for better experimental precision. Data from non-smoking areas collected during day 1 (samples 1 and 3) and during day 2 (sample 5) were normalized using the corresponding S values of sample 2 and sample 4, respectively. The results are plotted in Figure 2. ***Overall, concentrations of SHS tracers in non-smoking areas were not significantly different***

from those measured in smoking areas. In the case of nicotine, levels in the non-smoking area were between 68% and 129% of those measured in the smoking area. For most tracers, levels measured in the non-smoking area were between ~ 70% to ~ 120% of those in the smoking area.

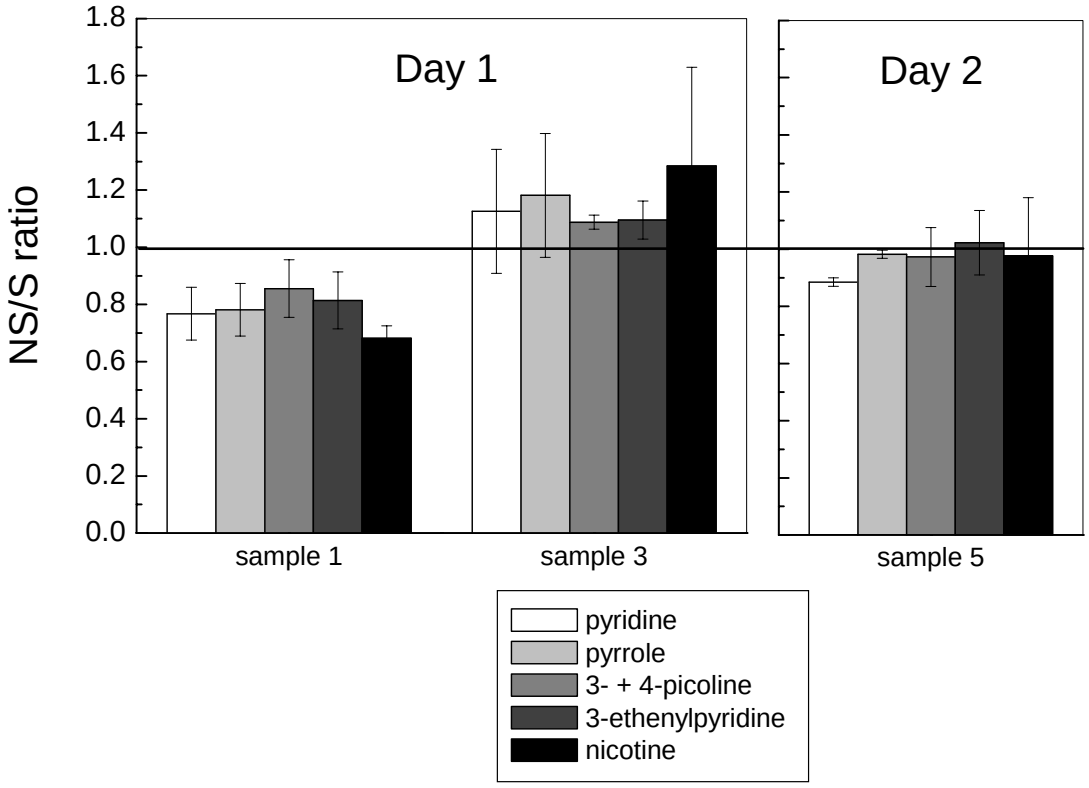

Figure 2: *Concentration of SHS tracers measured in the non-smoking area (NS) normalized with levels in the smoking area (S) (S samples were nr. 2 in day 1 and nr. 4 in day 2).*

In closer examination, we observed during day 1 a slow buildup of SHS over the whole 4-h sampling period, illustrating the degree of detail that can be obtained with this method. This upward trend was observed for all tracers, and was particularly notable for nicotine, for which concentrations increased almost twofold over the 4-h period, regardless of the sampling location (NS or S). This is particularly noteworthy because a large number

of smoking events were registered during sample 2 in close proximity to the sampling location, as indicated in Table 1. The effects of that large release of tobacco smoke determined not only an increase in sample 2 values as compared to the previous tracer levels measured in sample 1, but it also impacted sample 3 values. Despite being taken in the non-smoking area, levels of nicotine and other tracers in sample 3 were the highest of day 1, indicating that

a) SHS accumulated and increased during day 1 (samples 1, 2 and 3), and
b) diffusive and convective transport allowed for effective air mixing throughout the room.

Data from day 2 suggest that SHS tracer levels were constant during the sampling period (2.5 hours), and essentially the same values were measured in the smoking and the non-smoking areas.

Another important observation from this study is that nicotine compared very well with volatile gas-phase tracers that present a significantly lower tendency to sorb to indoor surfaces. The range of vapor pressures corresponding to tracers shown in Figure 2 spanned three orders of magnitude, from 20.8 to 0.038 mmHg. Such correlation between nicotine and gas-phase tracers is consistent with previous reports (LaKind et al., 1999), and indicates that nicotine is a good SHS tracer. Our measurements were carried out in conditions in which nicotine sorptive biases were minimal (Van Loy et al., 1998; Daisey, 1999). Specifically, indoor surfaces were likely saturated with nicotine due to long term and continuous exposure to high gas-phase levels of the alkaloid, thus minimizing possible nicotine sorption effects observed in “fresh” surfaces (Singer et al, 2002; Singer et al 2003). In addition, smoking followed a regular pattern, and the duration of the sampling period allowed for integration of a large number of smoking events.

Conclusions

A growing body of experience in the implementation of tobacco-control legislation in several countries uniformly suggests that only 100% smokefreee policies in public places and workplaces (as mandated by the FCTC and recognized by ASHRAE (Glantz

and Schick, 2004)) is effective in controlling exposures to SHS. Such smokefree policies have been implemented for several years in many cities and states in the US, and have recently been adopted by various European countries (Ireland, Italy, Norway and the UK) as well as by neighboring Uruguay. Smokefree workplace laws in California and New York have been very effective at reducing patron and employee exposure to tobacco smoke in bars and restaurants (Weber et al., 2003; Farrelly et al., 2005). Recent studies performed in Ireland before and after the implementation of the 2004 smokefree legislation showed that passive smoking and associated health risks were significantly reduced once the law was in place (Allwright et al., 2005; Mulcahy et al., 2005). A similar result was reported from studies carried out in Italy before and after a similar smokefree law for public places, showing a dramatic reduction in nicotine measured after the law entered into force in 2005. In that study, airborne nicotine measured in seven Italian pubs and discos was between 0.9% and 5.9% of values registered before the ban (Gorini et al., 2005).

The methodology proposed in the present study provides a simple and accurate method to assess the effectiveness of separation of smoking and non-smoking areas for SHS control, and can be a valuable tool to evaluate partial restrictions regimes. It can be carried out either in a sequential (i.e., quasi-simultaneous) mode, such as that described in this study, or by tandem sampling in smoking and non-smoking areas simultaneously. In both cases, this method provides a quantitative measure of the degree of exposure afforded by customers sitting in non-smoking areas. Our results suggest that the use of a simple indicator such as the NS/S concentrations ratio of one or more SHS gas-phase markers is an appropriate approach to evaluate nonsmokers' exposure. Our results indicate that customers sitting in the non-smoking area of this particular establishment were exposed to essentially the same level of toxic SHS components as those sitting in the smoking area.

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